Performance and Phosphorus Status of Range Cows with and without Phosphorus Supplementation

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Abstract

Performance and phosphorus (P) status were studied in 2 groups of range cows, one of which had free access to salt alone (control) and the other to a mineral mix (P-supplemented). The mineral mix contained 50% dicalcium phosphate, 45% salt, and 5% cottonseed meal. Performance traits (birth date, calving interval, weaning weight, suckling gain, and percent calf crop) were compared over 5 years (1979-83), one of which was considered a drought year (1980). Cows involved in the study received no supplemental protein or energy during the experiment. Lack of P supplementation had a detrimental effect on cow performance only when coupled with the effects of drought. This apparent combined effect delayed postpartum estrus in control cows during the 1980 drought, thus causing them to calve later (7 April vs. 11 February; $P<.05$) and wean lighter (226 vs. 253 kg; $P<.05$) calves in 1981 as compared to P-supplemented cows. Percent calf crop did not differ ($P>.05$) between the 2 groups during any year of the study, although in both groups, this trait was considerably lower in 1981 than in other years because of the 1980 drought. These results suggest that rainfall or P supplementation before and during the breeding season may be critical in maintaining early calving dates and heavier weaning weights but, even with P supplementation, lower conception rates may occur under drought conditions. Phosphorus status of cows was estimated from fecal, saliva, and rib bone biopsy samples collected at 6 intervals from April 1981 to January 1982. Fecal P varied ($P<.05$) among sampling dates and was higher ($P<.05$) for P supplemented cows than for control cows when averaged over sampling dates. Levels of fecal P were higher ($P<.05$) during the period of active forage growth than during dormancy. Salivary P peaked concurrently with fecal P; however, across sampling dates, response to supplemental P was inconsistent as evidenced by a treatment × date interaction ($P<.05$). During lactation, bone P levels were higher ($P<.10$) in P supplemented cows than in control cows. After lactation, bone P did not differ ($P>.10$) between groups and was higher ($P<.001$) than during lactation, which indicates bone P levels can be replenished following lactation without P supplementation.

Most phosphorus (P) nutrition research with grazing animals was conducted 30 to 50 years ago in the United States (Ross et al. 1948, Black et al. 1949, Knox et al. 1951) and in Africa (Theiler et al. 1928). These early studies reported aphosphorosis in cattle resulting from seasonal declines in plant P. Recent research in the United States and Australia has shown no difference in reproductive performance of beef females fed 65 or 100% of the National Research Council's (NRC 1980) requirement for P (Call et al. 1978, Little 1980), suggesting clinical aphosphorosis may not result from low P diets.

Measuring the mineral status of confined animals is a formidable task which is further complicated with grazing animals. Underwood (1966) suggested that phosphorus status of grazing animals is best determined by blood inorganic P level. In contrast, Gartner et al. (1965), Little and McMeniman (1973), and Cohen (1973) reported that plasma P levels do not adequately reflect P status. As a result, Little (1972) proposed a rib bone biopsy technique to measure P status of sheep and cattle. In addition, Cohen (1973) proposed measurement of dietary P level from blood, bone, saliva, and fecal P. The purpose of this study was to evaluate bone, saliva, and fecal P trends, and reproductive performance of range cows with and without P supplementation.

Experimental Procedure

Data for this study were collected at New Mexico State University's Fort Stanton Experimental Ranch, Lincoln County, New Mexico, on a site typical of the blue grama foothill-mountain rangeland of the Southwest. Vegetation in the study area is dominated by blue grama (*Bouteloua gracilis* [H.B.K.] Lag.). Other grasses include sideoats grama (*B. curtipendula* [Michx.] Torr.), galleta (*Hilaria jamesii* [Torr.] Benth.), sand dropseed (*Sporobolus cryptandrus* [Torr.] Gray), mat muhly (*Muhlenbergia richardsonis* [Trin.] Rydb.) and ring muhly (*M. Torreyi* [Kunth] Hitch.). Important forbs include carruth sagewort (*Artemisia carruthii* Wood), scarlet globemallow (*Sphaeralcea coccinea* [Pursh.] Rydb.) and Dakota verbena (*Verbena bipinnetifida* Nutt.). Open grassland vegetation exists on the mesas and canyon bottoms while slopes support sparse to dense stands of pinyon-juniper (*Pinus edulis* Engelm., *Juniperus* spp.) and wavyleaf oak (*Quercus undulata* Torr.) (Groce and Pieper 1967). Climate in the area is mild with warm summer days (mean maximum 28.9° C) and cool winters (mean minimum -6.7° C). The 94-year average precipitation is 348 mm with 228 mm (66%) occurring during the growing season of June through September (Parker et al. 1974). Precipitation during the growing season was 265 mm for 1979, 295 mm for 1980, 333 mm for 1981, and 370 mm for 1982. However, low precipitation during June and July of 1980 (June = 15 mm, July = 40.5 mm; 94-year average: June = 32.0 mm, July = 79 mm) created drought conditions. Above-average rainfall late in August (96 mm) and September (143 mm) was too late to stimulate forage growth during the breeding season.

Materials and Methods

In the spring of 1979, 78 Angus × Hereford cows were sorted by previous treatment and randomly allotted to 2 treatment groups (39 cows per group). One group (control) received only free choice salt, while the other group had free access to a salt:mineral mixture (50% dicalcium phosphate, 45% salt, and 5% cottonseed meal). Average monthly consumption of the salt and mineral mix is

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Table 1. Average supplemental consumption of salt and phosphorus by range cows with free access to either salt only or a mineral mix for 1980, 1981, and 1982.[1]

Treatment	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	NOV	$\bar{x}$
SALT ONLY													
NaCl(g)	1041	1377	1368	1436	918	900	968	868	1454	759	654	768	1043
MINERAL													
MIX[2] (g)	1550	2250	2250	1160	1430	910	1500	1670	1840	520	1030	1210	1450
P(g)	146	212	212	109	134	86	141	157	173	49	97	114	136
NaCl(g)	698	1012	1012	522	644	410	675	752	828	234	464	544	652

[1] Grams (g) per cow/month.

[2] Mineral mix contained 50% dicalcium phosphate, 45% salt, and 5% cottonseed meal.

shown in Table 1. No other supplements were fed. Each group was maintained on separate but similar pastures. Herds were rotated between pastures at periodic intervals when it appeared that erratic precipitation patterns might cause variation in forage availability or diet composition. Stocking rate varied from year to year but averaged 16 ha/cow annually.

Cow-calf performance records were maintained for each cow. Calving usually began in February of each year. Birth date and mid-October weaning weights were recorded for each calf. Heifer calf weaning weights were adjusted to a steer equivalent (weight × 1.05; USDA 1965). Cows were exposed to bulls on the range for 3 months beginning about 60 days post calving. All cows were pregnancy tested each fall at weaning time and open cows, along with those appearing unsound (e.g., cancer eye) and those over 11 years of age, were culled. This culling procedure was followed because it is typical of management practiced in commercial beef herds throughout the West.

An equal number (12) of cows from each treatment group was selected in the Spring of 1981 for bone, saliva, and fecal sampling. All sampling was carried out concurrently at various stages of cow production and plant growth during the period of April 1981 to January 1982. Because of approximately 1 month difference between the start of calving in the P-supplemented and control herds and a desire to sample cows in both herds at a similar stage of lactation, it was necessary to begin sampling on 24 April (P-supplemented herd) and 28 May (control herd). Range forage was in late dormancy following a drought year when initial samples were taken.

Other sampling dates and corresponding forage and animal stages were: 15 July, growing stage/mid-lactation; 16 August, maturity/late lactation; 16 October, early dormancy/weaning; 8 January, mid-dormancy/late pregnancy.

Fecal samples were collected to determine the relative intake of P between herds, as suggested by Cohen (1974). All samples were dried at 50°C for 48 hours and ground through a 1 mm-screen. Phosphorus was determined by the molybdovanadate colorimetric procedure on the nonsiliceous fraction of the solubilized ash (AOAC 1980). Saliva was obtained by wrapping commercially available cellulose sponges on a wood dowel and allowing cows to chew the sponge. This procedure was intended to produce saliva typical of actual mastication. After 5 minutes, saliva (approximately 6 to 10 cc/cow) was squeezed from the sponge into glass containers. At times, contamination resulted from food particles and soil. These inpurities were removed by centrifugation (100 × g, 5 min). Saliva samples were wet-ashed and analyzed for P by the same method used for fecal samples.

Rib bone samples were obtained to assess bone P reserves of the cows. Rib samples were obtained using a surgical technique outlined by Little (1972). This procedure involved clipping and sterilizing an area over the medial section of the 12th rib. A local anesthetic was administered and an incision (7.5 cm to 10 cm long) was made through the skin, fascia, and muscle to expose the rib bone. A trephine (1.2 cm in diameter) was used to cut the bone down to the medullary cavity which provided 700 to 900 mg samples. Fresh weights, dry fat-free weights, and specific gravity (fresh bone) were determined on each bone biopsy. Phosphorus content was determined using the molybdovanadate colorimetric procedure (AOAC, 1980). Bone P was then expressed as percentage of fresh bone and dry fat-free bone, as well as on a weight to volume basis (mg/cc bone).

Statistically, saliva and fecal P levels for all periods as well as bone for periods 1 to 5 (lactation period) were analyzed using analysis of variance techiques for split plot designs (Steele and Torrie 1980) with treatment tested against error A (cow/treatment). Period and the interaction (treatment × period) were tested against residual error. A paired t-test between lactating and non-lactating cows was used to evaluate observed differences in bone P. Performance traits (except percent calf crop) were analyzed using a completely random analysis of variance. The least significant difference procedure was used to compare least square means follow-

Table 2. Yearly performance traits of range cows with free access to either salt only (C) or a mineral mix (S) over a five-year period.

			Performance traits									
	Number (per trmt.)		Calving date[1] (day of year)		Calving interval[2] (days)		Weaning weight[3] (kg)		Suckling gain[4] (kg/d)		Calf crop[5] (%)	
Year/Treatment	C	S	C	S	C	S	C	S	C	S	C	S
1979	39	39	69^{a}	71^{a}	—	—	229^{a}	230^{a}	.91^{a}	.92^{a}	92^{a}	92^{a}
1980	33	37	59^{a}	59^{a}	355^{a}	353^{a}	237^{a}	227^{a}	.90^{a}	.86^{a}	92^{a}	100^{a}
1981	23	24	97^{a}	42^{b}	403^{a}	348^{b}	226^{a}	253^{b}	1.03^{a}	.91^{b}	72^{a}	67^{a}
1982	19	21	53^{a}	33^{b}	321^{a}	356^{b}	240^{a}	248^{a}	.89^{a}	.85^{a}	82^{a}	88^{a}
1983	13	13	54^{a}	45^{a}	355^{a}	377^{a}	236^{a}	245^{a}	1.11^{a}	1.11^{a}	100^{a}	100^{a}
Mean	25	27	66	50	361	359	234	241	.97	.93	88	89

[1] Calving dates are expressed as numerical day of the year (January 1 = day 1).

[2] Calving intervals are number of days between calving dates (from preceding to present year).

[3] Weaning weights are in kilograms (adjusted only for sex effect, heifer weights × 1.05, USDA 1965).

[4] Suckling gains are in kilograms per day from birth to weaning.

[5] Calf crops were calculated as the number of cows weaning calves in a given year plus any pregnant cows culled the previous year expressed as a percent of the cows exposed to breeding the previous year.

[a-b] Row means within trait with different superscripts differ ($P<.05$).

Table 3. Fecal and salivary phosphorus levels at various sampling dates during 1981-82 for range cows with free access to either salt only or a mineral mix.

Treatment	Sampling date April 24	May 28	July 15	August 16	October 16	January 8	Mean
	Fecal Phosphorus (% of DM)[1]						
Salt only	.18	.27	.31	.31	—	.11	$.24 \pm .01^{a}$
Mineral mix	.20	.27	.36	.42	—	.20	$.29 \pm .01^{b}$
Mean	$.19 \pm .03^{A}$	$.27 \pm .03^{B}$	$.34 \pm .03^{BC}$	$.36 \pm .03^{c}$	—	$.15 \pm .03^{A}$	
	Salivary Phosphorus (mg P/100 ml)[2]						
Salt only	3.33^{Aa}	2.51^{Aa}	4.85^{ABa}	6.44^{Ba}	2.30^{Aa}	2.29^{Aa}	$3.62 \pm .51$
Mineral mix	11.06^{Ab}	3.17^{BCDa}	1.96^{Ba}	5.55^{BCDa}	1.44^{BCa}	2.93^{BCDa}	$4.35 \pm .61$
Mean	7.13 ± 1.32	2.82 ± 1.80	3.35 ± 1.00	6.00 ± 1.31	185 ± 1.15	2.61 ± 1.43	

[1] Fecal P values for the October sampling date were not included due to inadequate sample size from several cows for laboratory analysis. No treatment × sampling date interaction was detected for fecal P levels ($P>.05$).

[2] A significant ($P<.05$) treatment × sampling date interaction occurred in salivary P levels.

[ab] Treatment means not followed by the same letter differ significantly ($P<.05$).

ing preliminary F tests (Cochran and Cox 1968). Calf crop data were analyzed by the method of Grizzle et al. (1969). Since the number of cows per treatment group varied among years, production data for each year were analyzed separately.

Results and Discussion

Cow-calf Performance

Performance data collected over a 5-year period are presented in Table 2. The number of cows per treatment decreased from 38 at the beginning of the study to 13 during the final year. Number of cows culled from the experiment due to unsoundness or failure to conceive did not appear to be treatment related during any single year. A substantial decline in number of cows per treatment occurred after the fourth year (1982) when a total of 12 cows were culled due to age (11 years old). Calving dates and calving intervals in 1979, 1980, and 1983 did not differ between ($P>.05$) treatments. However, in 1981, control cows had a longer ($P<.05$) calving interval (403 d) than supplemented cows (348 d), which suggests that breeding during the drought year (1980), coupled with a lack of P supplementation, delayed conception in control cows. The mechanism by which P influences reproduction has been attributed to energy metabolism (Cohen 1975). Control cows calved later ($P<.05$) in 1982 than supplemented cows (22 February vs. 2 February). This effect was not attributed to treatment, but rather to a carryover from the previous drought year, because control cows had a shorter ($P<.05$) calving interval (321 d) than supplemented cows (356 d). Data in this study suggest that fertility of range cows was not affected by P supplementation in near normal rainfall years. Cohen (1975) and Call et al. (1978) concluded that P supplementation of range cows had no effect on fertility. Contrary results were reported by Morrow (1969) and Playne (1972), who noted delayed conception and low fertility without P supplementation in pen-feeding studies.

Sex-adjusted weaning weights and suckling gain for calves are shown in Table 2. Age of calf adjustment for weaning weights was not made because of the large variation in number of days between birth and weaning in each herd. Mean weaning weight and suckling gain differed only slightly among treatments in 1979, 1980, and 1983. However, in 1981, following rebreeding during the drought year (1980), control calves (226 kg) were lighter ($P<.05$) at weaning than supplemented calves (253 kg). This difference in weaning weight was largely due to delayed calving of control cows in 1981 because suckling gain by calves was higher ($P<.05$) in the control herd than for those in the supplemented herd. Although control cows calved later than supplemented cows in 1982, no effect ($P<.05$) was noted on weaning weights (control = 240 kg, P-supplemented = 248 kg) or suckling gains (control = .89 kg/d, P-supplemented = .85 kg/d). Marked year differences were noted in percent calf crop from 1979 through 1983 (Table 2), but no treatment differences (P$P<.05$) within year were evident. The percent calf crop of cows averaged over both treatments for the 4 years following normal precipitation was 93.2%, compared to an average of 69.5 for the 1 year following a drought. The decrease of 23.7% in percent calf crop caused by drought was slightly higher than that reported by Bellido et al. (1981) from an earlier 5-year study in which 1 year was a drought year. Four years of data with 1 drought year are not sufficient to determine cause and effect relationships; however, there is an indication that P supplementation alone had no effect on reproductive performance or milk production of cows, or on daily gain of their calves.

Fecal Phosphorus

Least square means for fecal P by sampling date and treatment are shown in Table 3. Fecal values for the fifth sampling date were not considered in the statistical analysis because of an inability to obtain a sufficient quantity of feces from all animals for laboratory analysis, preventing meaningful analysis of data. Fecal P was

Table 4. Bone phosphorus levels (mg P/cc bone) at various sampling dates and by lactation status during 1981-82 for range cows with free access to either salt only or a mineral mix.[1]

Treatment	Sampling date April 24	May 28	July 15	August 16	October 16	Lactation mean[2]	January 8[3]	Mean
Salt only	144.3	162.0	154.3	142.8	149.8	150.7 ± 4.2^{a}	237.4	165.1 ± 4.1
Mineral mix	169.0	172.3	160.5	167.3	149.6	164.0 ± 4.9^{b}	233.0	175.3 ± 4.7
Mean	156.6 ± 10.3	167.1 ± 14.2	157.4 ± 8.8	155.0 ± 11.0	149.7 ± 8.3	155.8 ± 27.4^{A}	235.1 ± 11.1^{B}	

[1] Least square means ± standard errors.

[2] Lactation means represent mean of all values obtained from April through October sampling dates (the entire lactation period).

[3] January 8 means represent non-lactating levels.

[a-b] Treatment means over the lactation period differ significantly ($P<.10$).

[A-B] Lactation vs. non-lactating means differ significantly ($P<.001$).

affected by sampling date ($P<.05$) and treatment ($P<.05$). Supplemented cows had higher fecal P levels ($P<.05$) than control cows, which probably reflected the additional P consumed by supplemented cows from the free choice mineral mix. Mean fecal P (across treatments) were similar ($P>.05$) between the following sampling dates: April and January, May and July, and July and August (Table 3). Fecal P means indicate that this method may be sensitive to dietary changes. The steady rise in fecal P from 24 April to 16 August follows the increase in plant P noted by Pieper et al. (1978) as forage phenology progressed from dormancy to active growth. The decline in fecal P from 16 August to 8 January illustrates a similar decline in plant P with dormancy also noted by Pieper et al. (1978). These observations should support those of Cohen (1974), who found that fecal P was linearly related to dietary P levels.

Salivary Phosphorus

Salivary P least square means and standard errors for treatment with sampling date are shown in Table 3. A treatment by sampling date interaction occurred ($P<.05$); however, only on April 24 did mean saliva P content of control cows differ ($P<.5$) from that of supplemented cows. Salivary P levels peaked in August for both herds. This peak coincided with the rise in fecal P, which (as stated earlier) indicates a higher dietary P intake (Cohen 1974). Both herds showed declines in salivary P from April to May just prior to onset of lactation. Bailey and Balch (1961) reported similar results for P concentration of saliva when cows were fed diets of differing P content. Since P is cleared from blood primarily by the salivary glands in ruminants, salivary concentration should be indicative of relative blood levels and recycling. However, the P content of saliva is also a direct function of salivary secretion rates. Since rate of secretion could not be controlled, it is possible that the relatively high standard error reflects differences in secretion rate.

Bone Phosphorus

Bone P levels by sampling date, treatment, and lactation status are shown in Table 4. Only bone P expressed on a weight to volume basis (mg P/cc bone) was sensitive to treatment differences ($P<$). Overall, no treatment effects were noted. However, when treatments were evaluated with lactation status considered (periods 1 to 5 = lactating, period 6 = nonlactating) 2 responses were evident. First, lactating supplemented cows exhibited higher ($P<.10$) bone P than control cows. However, after lactation (8 January), control cows had higher ($P>.10$) bone P levels than supplemented cows. The lower bone P of lactating control cows compared with lactating supplemented cows may be a result of lower dietary P combined with depletion of bone P during late pregnancy and early lactation. Little and Shaw (1979) fed diets deficient in P and with excess P (65 and 135% of the NRC recommended requirement), but otherwise balanced, to steers and noted significant differences in bone P.

Phosphorus deficiency, according to Little and Shaw (1979), can be characterized in heifers (Hoey et al. 1982), sheep (Little and McMeniman 1973), and 18-month-old steers (Little and Ratcliff 1979) by bone P levels below 120 mg/cc, while levels above 150 mg/cc suggest P adequacy. These authors note that bone P levels above 150 mg/cc can occur in nutritionally deficient animals. In the present study, mean bone P by treatment or period did not fall below 150 mg P/cc bone. However, P levels below 120 mg/cc bone did occur a total of 8 times in different animals from both herds in our study.

The effect of lactation on bone P reserves is shown in Table 4. The mean bone P levels for lactating cows (periods 1 to 5) were lower ($P<.001$) than the mean for nonlactating cows (period 6). Control cows had slightly higher bone P after lactation stress was removed and made more rapid increases in bone P. This finding indicates that unsupplemented cows can recover as readily as their supplemented counterparts from a draw down of the body pool of P.

Our findings represent an antithesis to some earlier studies dealing with P nutrition of range cattle (Theiler et al. 1928, Black et al. 1949, Knox et al. 1951). Also, contrary to these early workers, Little (1975) observed no discernible performance response of cattle to low P diets (65% of the NRC recommended requirements), but he did note differences in bone P (expressed as mg/cc bone) between fully supplemented and low P groups.

Trends in bone, fecal, and salivary P, as well as those for performance traits, do not suggest strong relationships among any measurements studied. However 2 relationships are implied. First, recovery of bone P from lactation stress (period 5 to 6) was made during a low point in dietary P (as indicated by fecal P). Since actual dietary P levels were not determined, it is possible that forage consumed contained recommended amounts (0.18% P; NRC (1976). No attempt was made to measure forage P intake by cows used in the present study since it has been well established that grazed forage samples contain exaggerated P levels due to salivary contamination (Wallace et al. 1972). However, diet botanical composition studies by Pfister et al. (1984) on the same range type showed that the total grass component of cattle diets was higher in January (77%) than in November (61%). P content of grasses is usually lower than that of browse and forb species (Cordova and Wallace 1975). Moreover, studies of clipped forage (Pieper et al. 1978), which admittedly may not be truly representative of grazed forage, indicate a decline in P content of all grasses between November (.12% P) and January (<.10% P). Although present data do not describe exactly what occurred, one point seems clear; level of P absorbed by cattle appeared adequate for skeletal replenishment, energy metabolism and calf production.

Secondly, bone P levels were low during the breeding season (May to July). Salivary and fecal P were elevated during the period when dietary P should be increasing. During this early spring period, the cow's requirements are high (0.28% P; NRC 1976). However, dietary levels (based on fecal P) are not at a high point until after this period. Havstad et al. (1979) found that cattle diets on Fort Stanton during May to July contained primarily forbs (75% total forbs). Results of whole plant analysis (Cordova and Wallace 1975) indicate that these forbs are high in phosphorus (0.27%). Because similar rebreeding occurred in both herds, except during drought conditions, it appears certain that rainfall or P supplementation before and during breeding is critical.

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